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The Evolution of Corneal Refractive Surgery

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Refractive errors are some of the most common ophthalmic abnormalities worldwide and are associated with significant morbidity with recent population-based studies identifying them as the leading cause of visual impairment worldwide.[1] In North America for instance, as many as 1 in 5 people have some degree of myopia while several studies suggest up to 50% of the population may be hyperopic.[2] Traditionally, spectacles have been the mainstay of treatment. However, in cases where the patients suffer from severe myopia, hyperopia or astigmatism, eyeglasses have proven less than satisfactory for reasons such as optical distortion or significant inconvenience.[3] With the objective of improving on these shortcomings, contact lenses were introduced in 1960, but even this revolution in management is not without its disadvantages, requiring as it does, manual dexterity to insert and being associated with sight-threatening complications such as corneal ulcers and severe infection[1].

In the last 30 years, surgical procedures aimed specifically at altering the focusing or refractive properties of the eye have led to the development of what many now consider a bona fide surgical specialty in the field of ophthalmology. The range of surgical techniques for the rectification of refractive errors has been diverse, pioneering, and daring. The evolution of refractive surgery as a subspecialty has been driven by consumer/patient enthusiasm, a vigorous response by the ophthalmic profession, an enormous investment by the technical industry, and a relatively high overall degree of patient satisfaction.[4] This article aims to provide a historical account of the evolution of modern corneal refractive surgery from its modest beginnings to date.

The History of Non- Surgical Correction of Refractive errors

The earliest recorded attempt to rectify a refractive error was by the Greek philosopher Aristophanes who had serendipitously identified the magnification properties of glass [5]. However, it was not until approximately 150 AD that Ptolemy discovered the basic rules of light diffraction, writing extensively on the subject [5].

Most of the literature credits the religious teacher Sofronius Eusebius Hieronymus, (340 to 420 AD) as the inventor of spectacles [6] although the verity of this claim is ambiguous[5]. In numerous works of art he is portrayed with a lion, a skull and a pair of glasses and as a result has been made the patron saint of optometrists [5]. The first reliably documented use of spectacles was not until 1289 when in a manuscript, a member of the Popozo family wrote; “I am so debilitated by age that without the glasses known as spectacles, I would no longer be able to read or write” [6]. In the 15th century, the arrival of the printing press and mass produced books necessitated the design of inexpensive spectacles. This led to the era of the riveted spectacle consisting of two convex lenses connected by a nose bridge but without an overall-supporting frame. Edward Scarlet, an 18th century, British optician, improved on this with the invention of the rigid bridge spectacles which were superior in design to the riveted spectacles because they stayed in place even with head movement.[7]

The concept of contact lenses originated with Leonardo da Vinci in the 16th century when he contemplated the possible source of visual disturbances. Nearly a century and a half later, Rene Descartes proposed the idea of a corneal contact lens[7]. In 1801, Thomas Young a British physician developed a prototype based on Descartes’ idea, a inch long, water-filled glass tube, with a microscopic lens exterior, and used it to correct his own vision after first calculating the refractive strength required to rectify his visual defect[8]. Contact lens technology development did not begin in earnest for another 26 years when in 1827, British astronomer Sir John Herschel suggested creating contact lenses that could conform exactly to the eye’s surface. Sixty years later, Zurich-based ophthalmologist Eugene Fick reported treating a corneal disorder by creating lenses to be placed directly in the eyes on top of a layer of liquid[7]. However, the popularity of contact lens usage was not until the late 20th century when more comfortable designs had become available [7].

Contact lenses and spectacles have evolved in design over centuries in terms of comfort, appearance, safety and use of technology into the modern day standard. Despite these developments, corneal surgery started in the early 1900s, probably because the ultimate goal had always been to correct refractive errors permanently and rid people of the need to use either spectacle or contact lenses.

The History of Refractive Surgery

The objective of refractive surgery is to adjust the refractive state of the eye by altering the shape of the cornea [9]. Since the cornea is easily accessible and responsible for two thirds of the refractive power of the eye, the idea of altering the shape of the anterior surface of the cornea was deemed better than intraocular surgery involving the removal or the insertion of lenses [9]. Surgical procedures to alter the shape of the cornea date back over 130 years. 10 In 1896, a Dutch physician Leendert Jan Lans (working on his doctorate) performed systematic experiments using animal eyes, to study and define the principles of keratotomy[10]. He confirmed that transverse incisions could flatten the cornea in the perpendicular meridian. This was the origin of Radial keratotomy (RK).

Modern Refractive Surgery

RADIAL KERATOTOMY

In 1936, Tsutomu Sato observed that spontaneous breaks in Descemet’s membrane (figure 1) in patients with keratoconus, caused flattening of the cornea once healed [12].

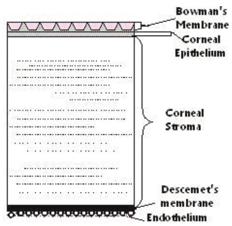

Figure 1. *Structure of the Corneal Stroma.*

In cases of trauma, it was noted that injury to Descemet’s membrane was greater than to Bowman’s membrane[12], suggesting that surgery on the posterior aspect of the cornea would be more effective. Three years later Sato devised a procedure to change the corneal curvature by making a horizontal incision in the corneal endothelium in patients with keratoconus.[12] Sato reported the safe use of posterior keratotomy to correct astigmatism and anterior’posterior corneal incisions to correct myopia in 1941 and 1943 respectively.[13, 14]

Since then the incidence of bullous keratopathy (fluid - filled blisters in the corneal surface) as result of Sato-type surgery has been on the increase [15]. Nearly all 300 RKs performed resulted in blindness owing to Sato’s approach in which incisions where made on the endothelial surface of the cornea[15]. Usually, the corneal endothelium provides a balance in hydration to maintain the cornea’s transparency, consequently endothelial disruption in RK leads to corneal swelling [16].

By the mid-1970s, Russian scientist Svyatoslov Fyodorov developed a method of anterior radial keratotomy where by a variation in the number of incisions and amount of uncut clear central zones between them, allowed him to control the degree of visual correction.[16] (figure 2).

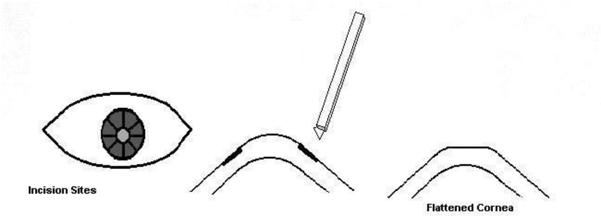

Figure 2. *Radial Keratotomy.*

Thus for the first time the medical establishment was convinced of the efficacy of RK as a method of myopia reduction and in 1980 the National Institutes of health sponsored the PERK (Prospective Evaluation of Radial Keratotomy) study which provided factual, scientific data on standardised radial keratotomies performed in nine centres across the United States[17]. Disadvantages of this procedure include blurred or washed out vision, pain, night vision problems, extended recovery time (about six months), residual astigmatism and irreversibility[16].

LASER REFRACTIVE SURGERY TECHNIQUES

The advent of the laser (Light Amplification System for Emitted Radiation) in the 1980s as an instrument used for reshaping the corneal stroma was a great step forward in refractive surgery [16]. The progression of this technique from a novel experimental area to its common use in millions of patients annually around the world has occurred in less than two decades. At different stages during the evolution of laser techniques, various problems were identified and overcome[16]. This has encouraged powerful commercial interests to vigorously advocate these approaches for routine refractive correction in lieu of traditional optical methods.

The main procedures currently utilised are photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) and a recently introduced (1999) modification of PRK, laser-assisted sub-epithelial keratectomy (LASEK) [16]. In PRK a laser is used to vaporise the anterior cornea (a pre-calculated thickness of Bowman's membrane and stroma) and create a thinner flatter central zone to correct the refractive error[16]. Some of the problems with PRK include pain, corneal haze or scarring, and the potential for infection creating a reduction in visual acuity and the procedure is usually permanent irrespective of outcome [16]. Advantages are that it is quick, more accurate than RK and enhancements if required are easier. The popularity of RK has declined because of the superior outcomes from PRK and LASIK18.

In LASIK, on the other hand, a corneal flap of about 130 to 160 microns deep is first raised with a microkeratome before the underlying stroma is ablated followed by replacing the flap[19] (figure 3 and 4).

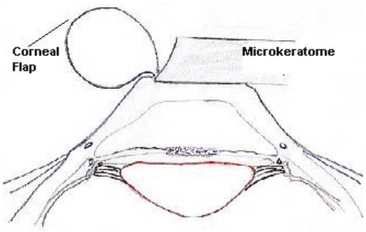

Figure 3. *The raising of a corneal flap using a microkeratome in Lasik.*

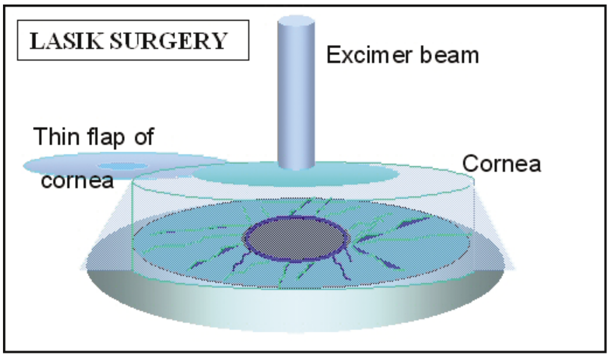

Figure 4. *The use of the excimer beam to reshape the cornea.*

This procedure showed much more promise than the RK or PRK techniques did but it was not without its complications[16]. These included flare and glare (if the patientís pupil size was not accounted for), poor night vision, loss of best spectacle aided visual acuity, irreversibility, irregular astigmatism and folds in Bowmanís membrane. Currently, it is the dominant procedure in refractive surgery[20].

The main advantage of the LASIK procedure over PRK is its maintenance of the central corneal epithelium[21]. During the early post-operative period, it increases comfort and allows for rapid visual recovery with a reduction in the wound healing response[21]. A reduction in wound healing correlates with less regression for high corrections and a lower incidence of complications such as haze due to stromal opacity.[21] For mild to moderate corrections PRK remains as an excellent option, especially in cases associated with thin corneas, recurrent erosions, or a predisposition to trauma[21].

In the LASEK procedure, a corneal epithelial flap is created using an alcohol solution, which is repositioned after ablation [22]. The benefits of the creation of an epithelial flap compared with the traditional PRK are not fully understood. Proponents of LASEK suggest that in the early postoperative period there is less discomfort, faster visual recovery, and less haze in comparison with standard PRK for correction of comparable levels of refractive error[22, 23].

A study by Kitazawa et al was able to demonstrate that LASEK achieved good uncorrected visual acuity, but there were some complications such as postoperative pain, delayed recovery of visual acuity, and corneal haze, meaning that a long and careful follow-up becomes a necessity[22]. Further long-term clinical trials, along with laboratory research, will be critical to the validation of the inherent advantages of the LASEK procedure.

In conclusion, corneal refractive surgery has advanced considerably in the past 130 years and with the more recent developments like LASEK, the use of spectacles and contact lenses for aided visual acuity may become a thing of the past if future prospective studies prove such techniques to be as effective and safe.

Conflicting Interests - None declared.

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